PREDICTING THE EFFECTS OF CLIMATE CHANGE ON MIGRATORY BIRDS AND BATS: *Quantifying the Gulf of Maine Flyway*

2010 Migration Monitoring Report

for Study # ACAD-00244 under Permit #: ACAD-2010-SCI-0053

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I. Introduction

Migration represents a critical time within the life cycle of many species. As much as 80-90% of annual mortality may occur during the migratory period (Sillett and Holmes 2002; Newton 2007). Thus, high quality "stop-over" habitats that provide species with food, rest, and a low risk of predation can lower the risk of migration (Bibby and Green 1981; Schaub and Jenni 2000, 2001; Hedenström 2009) and contribute to the long-term viability of migratory populations (Newton 2006; Haramis and Kearns 2007). The relative quality of migratory routes and migratory stop-over sites, however, have changed in the past under shifting climates and are expected to do so again in the future. To adequately manage migratory species across their range, we must understand the current use and value of migratory habitat. This will allow us to A) maximize the value of federal lands for migratory species, B) identify the habitat characteristics and species that are most likely to be impacted by climate change due to alterations in route quality, and C) identify changes in route use and route quality due to climate change when it occurs.

Across the western North Atlantic coast, documented corridors for migratory movement include the Connecticut River Valley, the southern New England coastline (including Cape Cod), and the Bay of Fundy (Lincoln et al. 2002). Little is known, however, about the relative use of the Atlantic Coast and the thousands of coastal islands from Southern New England to the Bay of Fundy by migratory species. Radar and ceilometry studies have revealed large movements of birds and bats moving well offshore in the Gulf of Maine, and these movements were not always the result of bad weather conditions. This suggests that many species purposefully make large-

scale movements over the water (Drury and Keith 1962; Williams et al. 1981; Richardson 1978; McClintock et al. 1978).

Shorelines are widely known to concentrate migratory movements of both birds and bats, which typically avoid long, open-water movements without favorable weather conditions (Lack 1960; Richardson 1978; Yaukey and Powell 2008). The east-west orientation of the Maine coastline has the potential to concentrate large numbers of migratory species, especially if they gather along the coast to await favorable weather conditions before crossing the Gulf of Maine during the fall. Well-known migratory concentrations due to similar geographic arrangements are regularly seen in North American along the shores of Cape Breton, the Great Lakes, the Gulf of Mexico, Cape May, and Key West, along with a long list of additional birding hotspots worldwide.

Recent monitoring during the fall of 2009 on Metinic Island (16km off the Maine Coast) uncovered a new potential hotspot of bird migration, with an estimated 500,000 birds stopping on the 130 ha island between August and October of this last year alone (Leppold 2009). On several days during the migration period, as many as 1,000 birds were observed at once, resting and moving about on the ground and low-lying vegetation in the immediate banding area (A. Leppold, pers. obs.). Visual observations during daylight hours revealed that the majority of birds, in flocks ranging from a few dozen to several hundred, approached the island from the northeast and east and departed the island heading west and southwest, with most birds flying at or below 200 m above sea level. Such high concentrations of migrants within a small area could represent a critically sensitive period within the annual cycle of many species. Habitat loss or degradation at these critical locations due to climate change or landscape development has the potential to impact population viability across a wide swath of high latitude breeding areas.

To conserve high latitude birds and bats in an era of climate change, we must understand what migratory species utilize the Maine Coast, how key areas support the high energetic demands of migration, and how consistent this use is from year to year. Short-term efforts are important, but as migratory behavior is inherently variable (and likely to be more so under climate change and landscape development), we need to establish a monitoring platform across the Gulf of Maine that will allow managers to predict animal land use based on weather, location, and habitat attributes. Such a platform will allow us to develop a predictive model of animal migration that allows for more effective, comprehensive management.

II. Banding Site Selection and Habitat

To augment current monitoring stations on Metinic Island (R. Holberton, PI), Appledore Island (S. Morris, PI), and three stations in Nova Scotia (P. Taylor, PI), we established three stations across the Gulf of Maine that vary in both their distance from the mainland and their position within the Gulf, yet possess the same relative habitat types (i.e. spruce and hardwood forest, mixed upland shrub, grazed or mowed grassland, cobble beach, and intertidal ledge: Leppold 2009). This design will eventually allow us to predict migratory movement across the Gulf of Maine as a function of location within the Gulf, distance from the mainland, and habitat type. The most northern of our three sites, MacFarland Hill, is located on Mount Desert Island (MDI), ~10-km inland from the mouth of Frenchman Bay. The second site, Seawall, is located on the southernmost coastline of MDI (~5-km further south than the mouth of Frenchman Bay), and the third site, Great Duck Island (GDI), is ~11 km further out in the Gulf of Maine from the Seawall site. Great Duck Island is a 74-ha island and the first treed island that migrating animals would encounter flying southwest out of the Bay of Fundy.

The three sites were operated with partnered support from the National Park Service, the University of Maine, the College of the Atlantic, and the Nature Conservancy. All three of these sites possess the major habitat types found at the other stations currently operating across the Gulf of Maine. Such a blocked design is critical for disentangling the effects of habitat from the effects of distance from the mainland. Maps of the three sites are located in Appendix A.

Nets were placed in the five habitat types shown in Table 1 based upon the percentages of habitat at each site. All sites contain the five types except Seawall, which lacks field/forest edge. Between two and four nets were placed in each of the habitat types at each site. Habitat types and UTM's for all nets are provided in Appendix B

Table 1. Habitat type description

Habitat Classes		
1	**Field**	Largely open habitat dominated by grasses, forbs, and low-lying ericaceous shrubs <1 m tall. All nets were placed in front of a single tree of shrub or small copse of trees or shrubs less than 5-m wide at the widest point within this habitat type.
2	**Field/Shrub Edge**	The transition between field (as defined above) and shrub habitat (with a distinctive shrub canopy < 5 m and no cohesive tree canopy, although isolated trees > 5 m may be present). All nets were placed along the edge of a shrub patch that continued for more than 5 m perpendicular to the net center on one side with field on the other side, or nets were placed with one end anchored in the field, running directly into the shrub thicket
3	**Shrub**	Nets were placed in areas completely surrounded by shrub habitat (as defined above) on all sides for at least 5 m.
4	**Field/Forest Edge**	same as 2 except for trees (> 5 m) instead of shrubs (< 5 m)
5	**Forest**	same as 3 except for trees instead of shrubs

III. Operation Methods

We opened nets 30 minutes before sunrise and continued capture for six hours if conditions permitted. The specific nets and the total number of nets opened on any given day varied by weather conditions, most commonly with the presence of strong winds or rain. When nets were closed for reasons other than weather, such as a large volume of birds or a shortage of net operators, we closed nets to allow continued operation in every habitat type. We checked nets every 30 minutes, more often during windy conditions. All birds were then placed in cloth bags and brought back to a central banding station for processing. We placed a USGS-BBL aluminum band on all new captures and recorded age, sex, wing length to the nearest 0.5 mm, subcutaneous fat (on a scale from zero to five), mass to the nearest 0.1 g, and the time of banding. We also collected tarsus, culmen, and exposed culmen lengths to the nearest 0.5 mm when time permitted. Extra bill measurements were taken for some sparrow species as part of JDM's graduate research at the University of Maine.

IV. Banding Season Summary

We banded on 48, 47 and 37 out of a possible 51 days between 24 August and 14 October at Seawall, MacFarland Hill and GDI, respectively. At Seawall nets were open for 3,280 hours, capturing 1,232 individual birds for a seasonal mean capture rate of 0.38 birds/net hour. MacFarland Hill's nets were open for a total of 3,134 hours, capturing 1,197 birds for a similar capture rate of 0.38 birds/net hour. Great Duck Island had the highest capture rate of the three sites at 0.62 bird/net hour with 940 new birds captured during 1,887 net hours, a 60% increase over the two more inland sites.

Capture Rates by Habitat Type

Although Great Duck had the lowest net hours due to high winds in the open habitats, the capture rates for all nets was higher than at both MacFarland Hill and Seawall. The forest habitat had the lowest capture rates for all three sites, although the species captured in this habitat were clearly distinct from those captured elsewhere. The field nets at GDI were only opened for 72 hours, 4% of the total season's hours, but during this sampling frame their capture rate was roughly equal to the other habitat types on the island. Habitats including a shrub component captured the most birds for all sites, although this might represent a mist-netting bias.

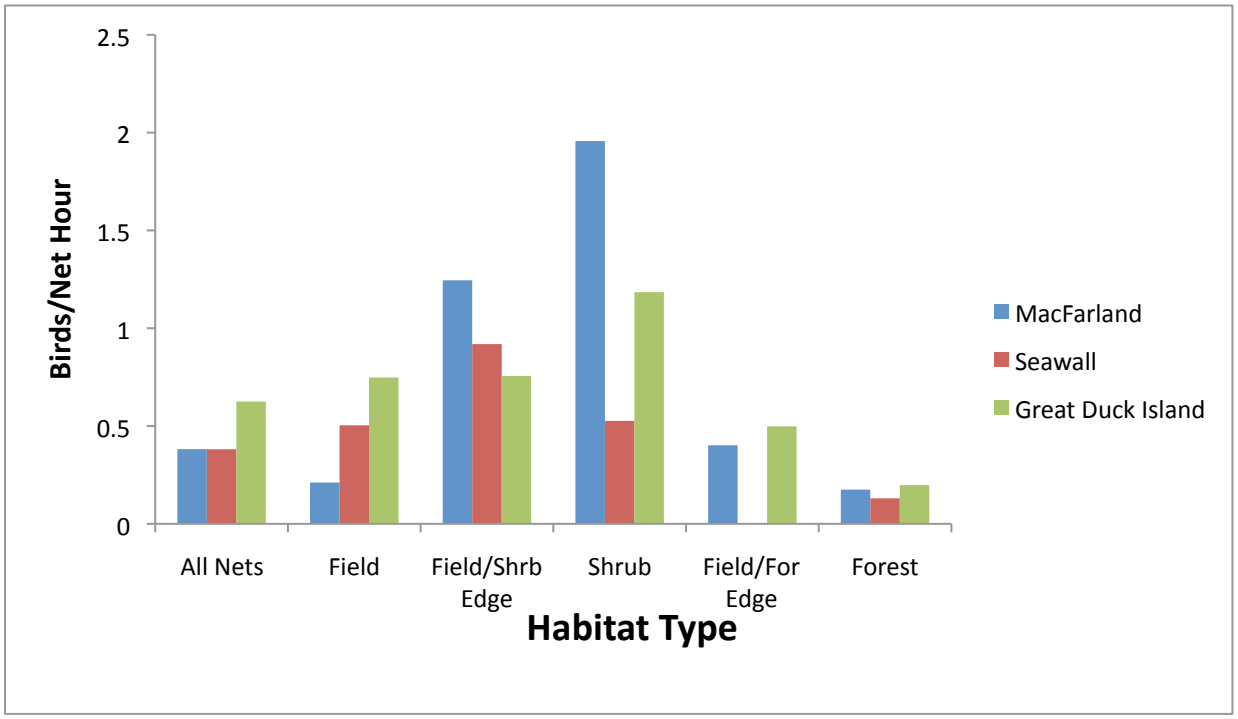

Figure 1. Capture rates by habitat type for all banding stations (there were no nets placed in Field/Forest edge at the Seawall Site)

Capture Summary by Site

We banded 61 different species of birds this season at Seawall. Black-capped Chickadee *(Poecile atricapilla)* dominated the catch this fall, making up 26% of the total captures. The next most abundant species were Yellow-rumped ("Myrtle") Warbler (*Dendrioca coronata*) and Song Sparrow (*Melospiza melodia*) comprising 8% and 6% of the total captures, respectively. Table 2 provides the top ten species list for the fall season (for a full summary of species' totals, reference Appendix B). Of the top ten, Common Yellowthroat (*Geothlypis trichas*), Golden-crowned Kinglet (*Regulus satrapa*), Swamp Sparrow (*Melospiza georgiana)*, Black-capped Chickadee, and Song Sparrow are confirmed breeders in Acadia National Park, although the pattern of capture likely encompasses site, local, regional and larger scale movements.

Capture rates at Seawall were fairly consistent throughout the season with a distinct increase on 4 October (Figure 2). This may partially be due to sampling variance as nets were only open for a combined total of 8 net-hours during that day due to weather. During the limited operation, however, we captured four species of sparrow, two warbler species, red-eyed vireos and a Black-capped Chickadee.

Table 2. List of the top ten species banded this fall at Seawall, Maine

Species	Season Total
Black-capped Chickadee	325
Myrtle Warbler	106
Song Sparrow	83
White-throated Sparrow	82
Gray Catbird	70
Red-eyed Vireo	63
Swamp Sparrow	62
Golden-crowned Kinglet	48
Common Yellowthroat	36
American Robin	35

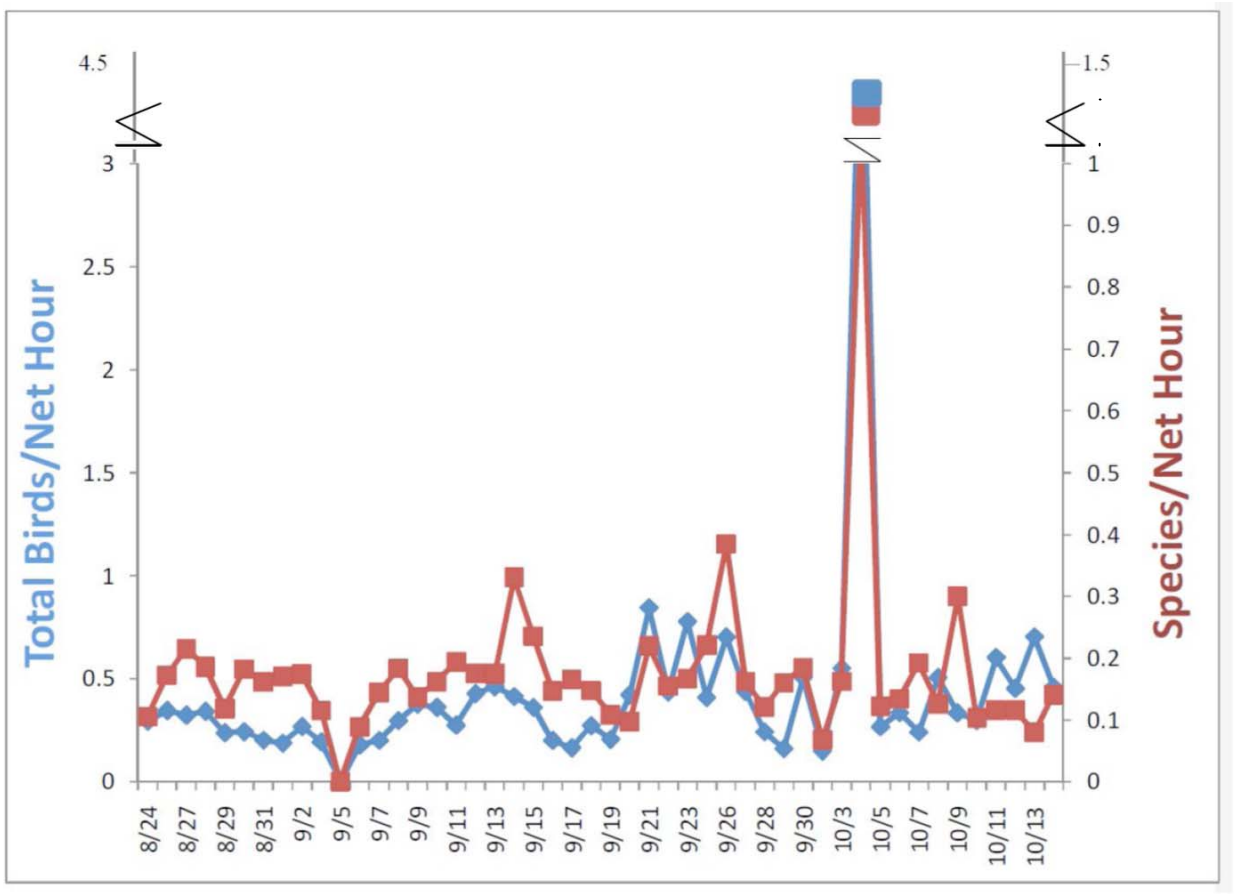

Figure 2. Capture rates for total captures (diamonds in blue) and number of species (squares in red) by day in Seawall, Maine. Zig-zag lines indicate a break in the scale.

We banded 59 different species of birds this season at MacFarland Hill. Myrtle Warbler dominated the catch this fall, making up 66% of the total captures. The next most abundant species were White-throated Sparrow (*Zonotrichia albicollis*) and Black-capped Chickadee comprising 6% and 5.5% of the total captures, respectively. Table 3 provides the top ten species list for the fall season (for a full summary of species' totals, reference Appendix C).

Table 3. List of the top ten species banded this fall at MacFarland Hill, Maine

Species	Season Total
Myrtle Warbler	644
White-throated Sparrow	54
Swainson's Thrush	50
Black-capped Chickadee	42
Slate-colored Junco	41
Hermit Thrush	38
Red-eyed Vireo	32
American Robin	30
Song Sparrow	23
Northern Waterthrush	19

The MacFarland Hill site had very low capture rates for August and early September (Figure 3). Capture rates increased in mid-September and remained steady through the end of the month. A second peak of movement occurred in the last week of capture. The trends in capture rate were driven largely by variance in the capture rates of Myrtle Warbler alone, where high capture rates correspond to days when large flocks of Myrtle Warblers were passing through and utilizing the bayberry shrubs.

We banded 66 different species of birds this season at GDI. Cedar Waxwing (*Bombycilla cedrorum*) dominated the catch this fall, making up 21% of the total captures. The next two most abundant species were Red-eyed Vireo (*Vireo olivaceus)* and White-throated Sparrow comprising 11% and 7.5% of the total captures, respectively. Table 4 provides the ten most common species captured during the fall season (for a full summary of species' totals, reference Appendix C).

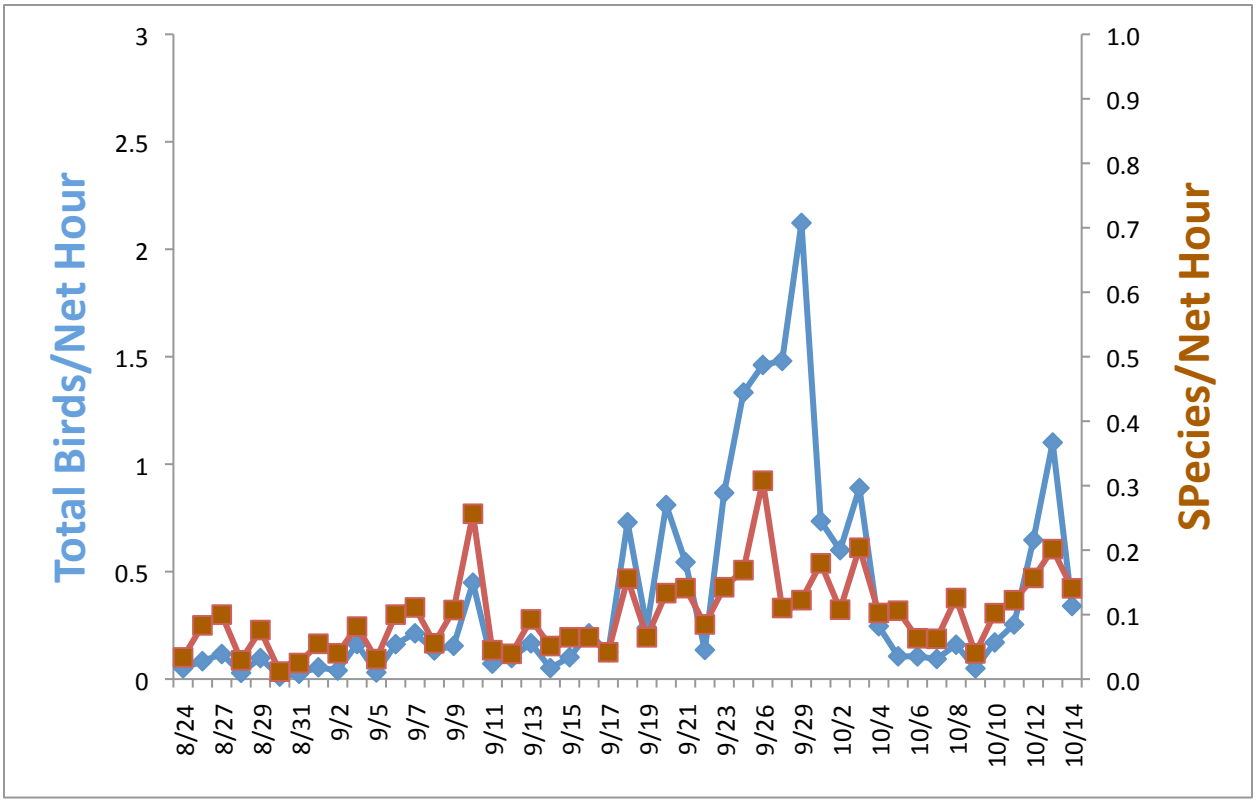

Figure 3. Capture rates for total captures (diamonds in blue) and number of species (squares in red) by day on MacFarland Hill, Maine

Table 4. List of the top ten species banded this fall on Great Duck Island, Maine

Species	Season Total
Cedar Waxwing	171
Red-eyed Vireo	95
White-throated Sparrow	48
Golden-crowned Kinglet	47
Yellow-shafted Flicker	47
Song Sparrow	37
Slate-colored Junco	33
Purple Finch	32
Brown Creeper	28
Trail's Flycatcher	26

Capture rates for GDI varied the most throughout the banding season with peaks of high capture rates in mid September, late September, and early October (Figure 4). GDI showed the greatest variance in sampling effort as well, so it is difficult at this point to disentangle sampling variance from site and weather-related variance in bird habitat use. The high capture rate for 4 September can be largely contributed to the capture of 54 Cedar Waxwings (34 warblers from 8 species were also captured on that day).

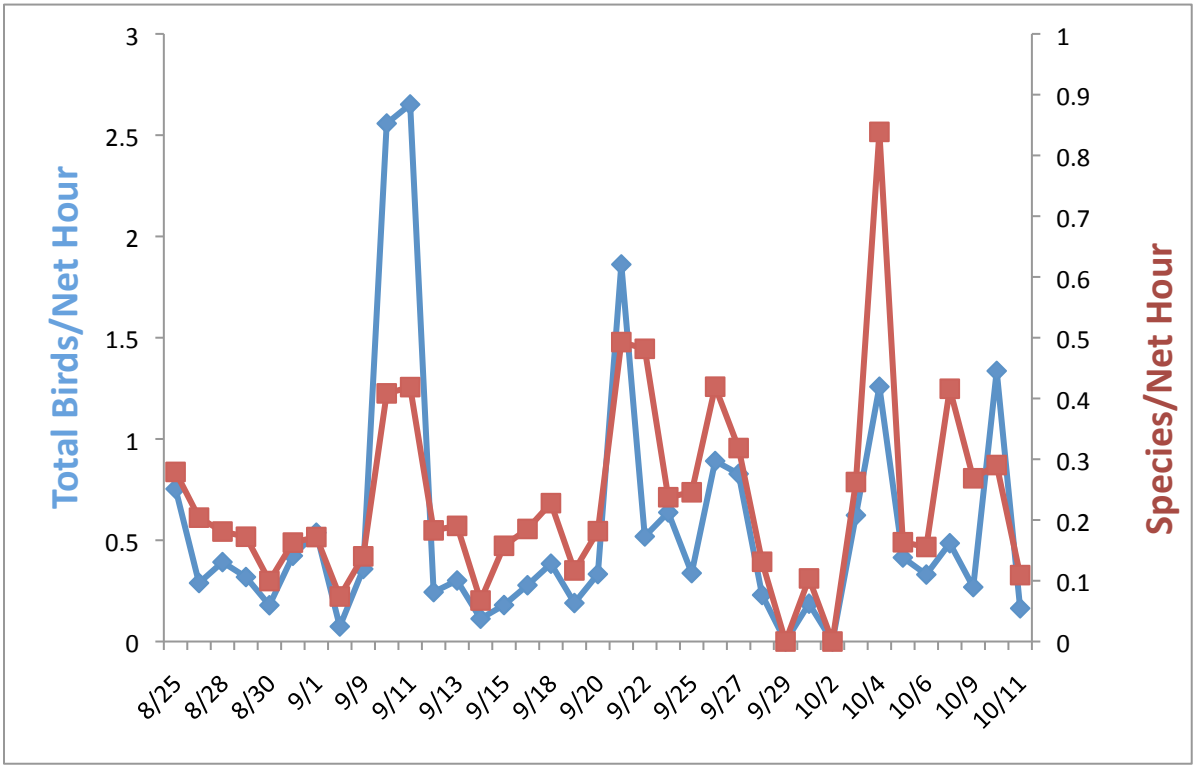

Figure 4. Capture rates for total captures (diamonds in blue) and number of species (squares in red) by day on Great Duck Island, Maine

Recaptured and Unbanded Birds

In addition to the captures described above, we recaptured 245, 161 and 68 of our banded birds at Seawall, MacFarland Hill and GDI, respectively. All but one of the recaptures was banded earlier in the season at one of our sites. A Yellow-shafted Flicker banded in Nova Scotia

during fall migration 2007 was recaptured 23 September on GDI. Seawall had more recaptures than either MacFarland Hill or GDI, which could suggest differences in migratory stopover behavior due to site or merely represent differences in the species sampled (although these alternatives are not mutually exclusive). Twenty-eight percent of Seawall's recaptures were Black-capped Chickadees, a resident species. Myrtle Warblers comprised 66% of the birds recaptured at MacFarland Hill. Recaptures on GDI were much more varied, with Song Sparrows recaptured most frequently (22% of the recaptures).

We released 49, 79 and 132 unbanded birds at Seawall, MacFarland Hill and GDI, respectively. Unbanded birds include birds that we observed bouncing out of the net, that escaped sometime before being banded, or were released at the net, because they were either in poor condition or exhibiting signs of stress.

Interesting and Unusual Captures

Some species of interest captured at Seawall this fall included: American Woodcock (*Scolopax minor)* (left unbanded), Black-billed Cuckoo (*Coccyzus erythropthalmus*), Yellow-billed Cuckoo (*Coccyzus americanus*) (Figure 5), Nelson's Sharp-tailed Sparrow (*Ammodramus nelsoni*), and Yellow-breasted Chat (*Icteria virens*). We captured an average of five Ruby-throated Hummingbirds (*Archilochus colubris*) at each of our sites. They were not included in the totals because we did not have the appropriate permits to band them; however they are included in the unbanded totals. A vagrant hatch-year Painted Bunting (*Passerina ciris*) was captured on GDI on 22 September, Figure 6.

An interesting and unexpected finding was breeding Carolina Wrens (*Thrypthorus ludovicianus*) on GDI. Carolina wrens are a resident species throughout their range, and

although they have been found in Maine in recent decades, they are largely confined to the southern part of the state, along the edges of mixed hardwood forest and in suburban yards, habitat types that do not exist on GDI, which is dominated by mixed spruce stands. The banding staff on GDI watched at least one family group near the banding station throughout the fall season, and one technician reported hearing them during the summer on GDI and on nearby Little Duck Island during the course of a different project (M. Dickinson, pers. com.). The family group near the banding station appeared to be using a large grouping of spruce blow-downs, which are common on the island. One adult and two hatch-year wrens were captured and banded this fall. Each wren was given a unique color-band combination in hopes of watching them over the next couple of banding seasons. Although this is not the most northern breeding population of Carolina Wrens, it is far north of reliable Carolina Wren populations, and the habitat association on GDI is certainly unique for the species and representative of even more northern climes where Carolina Wrens are absent. The observation may represent an increase in niche breadth and habitat generalization in a species that is actively expanding its range northward (Wells et al. 1998).

Figure 5. Yellow-billed Cuckoo

Figure 6. Hatch-year Painted Bunting

V. Daily Bird Observations

Fixed Area Surveys

Fixed area surveys were conducted in all habitat types beginning 9 September through 13 October, weather permitting. Two 15-minute surveys were completed each day, rotating through the habitat types. The survey area ranged between 1.3-6.1 hectares in size. The borders of the survey areas were heavily flagged and only birds inside the flagging were counted. We prioritized the number of birds seen as the highest priority in terms of data collection, followed in decreasing order by general taxonomical group (e.g. warbler, sparrow, blackbird), species, and sex when these designations did not compete with the collection of higher prioritized data. A complete area survey protocol can be found in Appendix D.

More birds were detected on average in the shrub habitat (Figure 7). MacFarland Hill's high shrub detections can be contributed to the influx of migrating Myrtle Warbler that were feeding among the bayberry shrubs. Great Duck Island had relatively consistent detections among the four habitat types (although the field survey area also possessed a shrub component at Great Duck Island), the highest being the edge habitat. These results were reasonably consistent with the relative capture rates within each habitat (Figure 1).

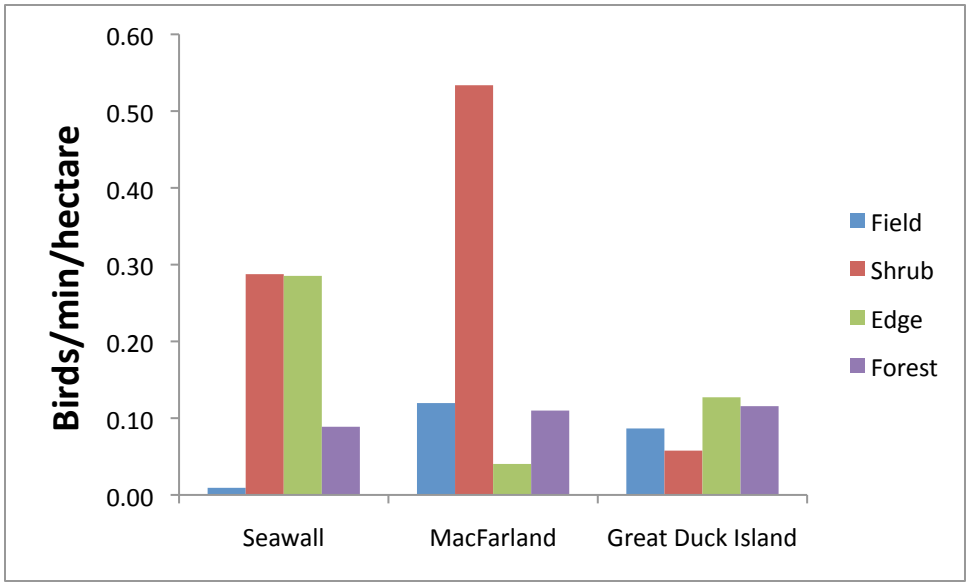

Figure 7. Results for fixed area surveys

Raptors

In order to gauge predation pressure for migrants, we recorded all predator sightings while banding (Table 5). Great Duck Island observed significantly more raptors then MacFarland Hill or Seawall. Primarily in mid-September, Merlins were seen chasing Yellow-shafted Flickers on GDI in considerable numbers. At all three sites, Sharp-shinned Hawks were caught attempting to grab songbirds from the nets. Two White-crowned Sparrows were killed at MacFarland Hill and Seawall during these attempts.

Table 5. Raptor sightings made while banding for all three sites

Species	***Great Duck Island***	***MacFarland Hill***	***Seawall***
Accipiter sp	1	0	0
American Kestrel	20	1	1
Bald Eagle	34	1	1
Broad-winged Hawk	0	1	1
Coopers Hawk	5	0	2
Falcon sp	1	2	0
Merlin	52	0	8
Northern Harrier	15	2	2
Peregrine falcon	11	1	1
Sharp-shinned Hawk	45	14	14
Unknown Raptor	0	4	0
Unknown Buteo	0	5	0
Total	***115***	***31***	***30***

VI. Weather

Some noteworthy weather events from the fall banding season were a heat wave at the end of August and a hurricane in early September. The week leading up to the hurricane was unseasonably warm. Temperatures were regularly in the 90's. Nets in the direct sun were closed before 10am during this entire weak. Hurricane Earl then hit the coast of Maine on 4 September. As a precaution, we took all nets down and evacuated the GDI crew on 2 September.

VII. Vegetation

Data was collected to quantify the vegetation of the sites in general and the habitats sampled within each site by mist-netting stations and the fixed-area censuses. The data collected has an emphasis on vegetative structure and foraging resources.

The protocol consists of vegetative characterization on two time scales (weekly and once per season) at a small spatial scale that can be combined to assess larger spatial scales. The intent of this design is 1) to allow for tests of covariation between local habitat and the results of mist-netting and fixed-area censusing and 2) to allow for a consistent characterization of the overall sites sampled at different sites.

Assessments of leaf cover and fruiting vegetation was done for all net lanes on a weekly basis. During each visit the species of fruiting plant, the state of fruit ripeness, and the rough abundance of fruit were recorded, as well as the percentage of leaf-drop for both the tree canopy and the shrub canopy. The vegetation data has not yet been analyzed and will be included in the next report. A complete protocol can be found in Appendix E.

VIII. Acoustics

We operated passive acoustic recorders (Wildlife Acoustics SM2 with one ultrasonic and one standard microphone) from one hour before sunset to one hour after sunrise to record the calls made by flying bats and birds, which will allow us to estimate the diversity and abundance of animals migrating over the site. Automated algorithms (Song Scope Version 3.0, Wildlife Acoustics Inc.) trained by local recordings will determine species identity and estimate abundance for each night. Because of unforeseen equipment failures and Hurricane Earl, recorders were deployed later then the start of banding. The recorders ran from 10 September to 13 October at MacFarland Hill and 20 September to 9 October on GDI. Seawall's recorder was short circuited due to operator error during deployment, rendering it useless. A different recording device (Olympus DM-420) was deployed at Seawall to replace the nonfunctioning

unit. A second Olympus recording device was also deployed at MacFarland Hill on 27 September to 3 October to compare the relative detection probabilities of the two different recording devices for interpretation of the data collected at Seawall. None of these data have yet been analyzed.

IX. Visitors

All three sites received visitors, with Seawall receiving the highest number because of the station's location near a heavily visited destination within Acadia National Park. Families and couples stopped by Seawall for an average of 30 min, 3-4 times a week. The banding crew would explain the project and its involvement in the larger migration-monitoring network in the Gulf of Maine. The visitors observed the birds being banded and occasionally would accompany a crew member to the nets. Acadia National Park interpreters were brought to Seawall by Bruce Connery on two separate occasions, 27 September and 12 October. These visits were to introduce the project to park employees, as well as to discuss the possibility of using one of the banding stations as an environmental education experience for groups visiting ANP.

There is not a public ferry to GDI; therefore the only visitors to the banding station were brought by COA. John Anderson, a COA professor, brought an ecology class of 10 undergraduates to the banding station while on a field trip to GDI.

The MacFarland Hill site is not visible to casual park visitors. The site was visited by two Park Naturalists who had heard about the project and wanted to find out more.

X. Acknowledgements

This project would not have operated as smoothly as it did without everyone's enthusiasm for early mornings and hard work. We would especially like to thank Bruce Connery, Acadia National Park's Wildlife Biologist, for all the extra hours he spent making sure we had everything we needed, whether that was man-power, a vehicle, or rubber boots. Bruce was always available to answer questions or just to talk about the project.

This fall we had the pleasure of working with a great crew of experienced banders (A. Byrd, E. Dittmars, D. Grunzel, A. Levoy, and J. Roelke), College of the Atlantic interns (C. Carlson and M. Dickinson), Park Service staff (B. Wheeler and J. Williams), and volunteers (R. Gerber and D. Bridges). The interest and drive of the interns and volunteers was inspiring.

We would also like to thank members of the wider migration monitoring effort for helping our efforts here remain comparable to the larger-scale project, including Adrienne Leppold and Rebecca Holberton at the University of Maine for organizing a pre-season banding training session, writing out the banding protocol, and answering a suite of questions along the way, and Sara Williams and Steve Agius at the Maine Coastal Islands National Wildlife Refuge for helping develop the vegetation protocol and supplying some critical last-minute auditory equipment. Thanks also to Brian Mitchell at the Park Service and Jon Katz at the University of Vermont for helping us find the last-minute materials we needed and for trouble-shooting the endless smaller technical hurdles.

Finally we would like to thank Nancy Sferra for access to the Nature Conservancy lands on Great Duck Island and the use of three cabins there. Most of all, we owe sincere thanks to John Anderson and the College of the Atlantic for access to the island, the use of the house, two

sensational interns, and boat trips to and from Great Duck Island that ferried both people and supplies to the crew stationed there. We look forward to working with him again next season.

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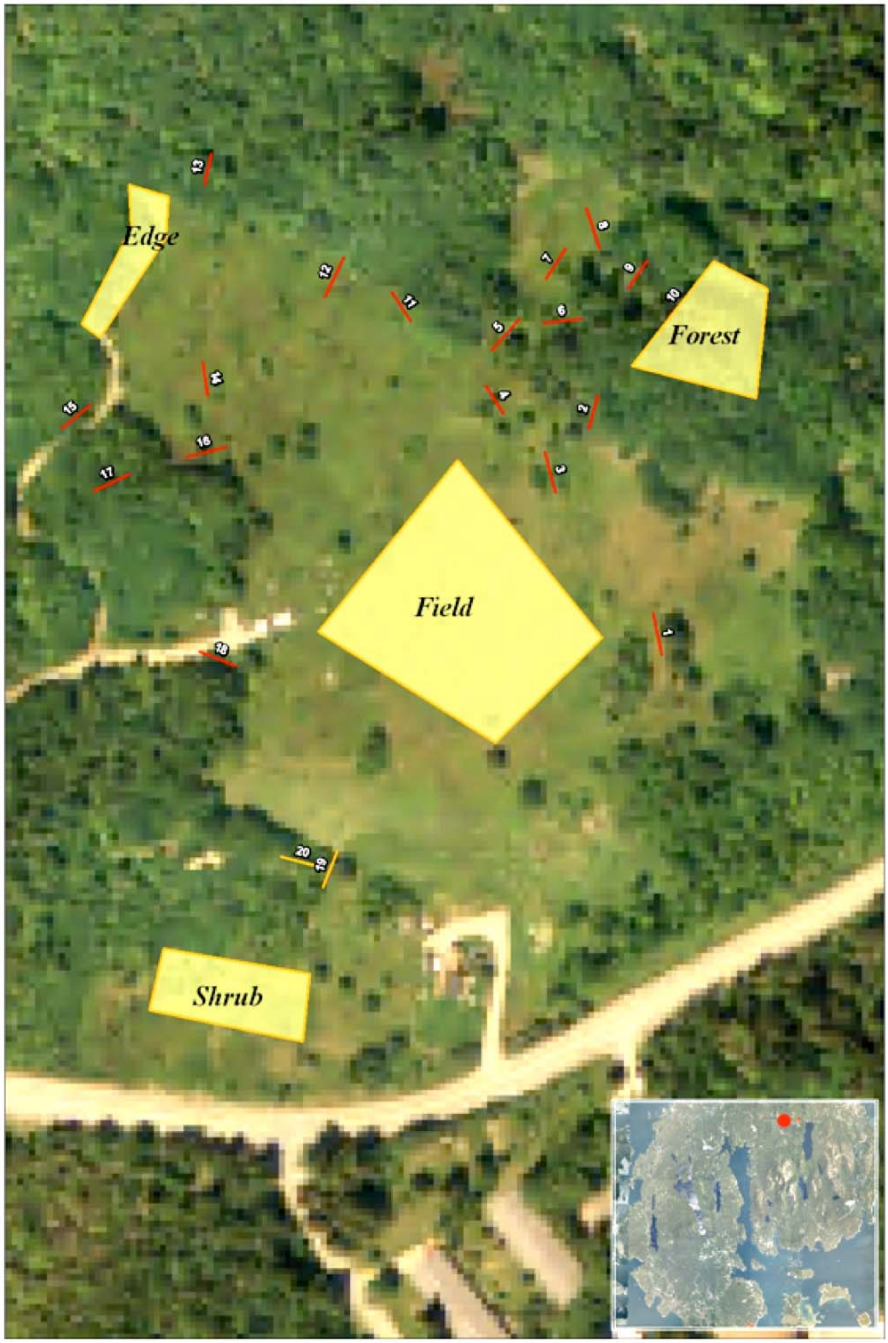
XII. Appendices

Appendix A. Site Photographs and Nest Placement Maps

Map 1. Fixed-area surveys plots (yellow polygons) and mist net placement (red lines) of 20 nets at MacFarland Hill. Inset shows the location on Mount Desert Island, Maine



Map 2. Fixed-area surveys plots (yellow polygons) and mist net placement (red lines) of 20 nets at Seawall. Inset shows the location on Mount Desert Island, Maine

Map 3. Fixed-area surveys plots (yellow polygons) and mist net placement (red lines) of 20 nets at Great Duck Island. Inset shows the location on the island (large red dot) in relation to the Seawall site (small red dot) on Mount Desert Island, Maine.

Appendix B. Net Locations and Habitat Classes

Great Duck Island					
		Start		End	
Net	Habitat Class	Easting	Northing	Easting	Northing
1	Shrub	560127	4889263	560132	4889267
2	Shrub	560137	4889263	560119	4889259
3	Shrub	560126	4889262	560128	4889250
4	Field/Forest	560094	4889286	560099	4889280
5	Field/Forest	560116	4889309	560102	4889309
6	Field/Forest	560132	4889303	560121	4889302
7	Forest	560102	4889339	560104	4889326
8	Forest	560111	4889343	560122	4889345
9	Forest	560073	4889354	560074	4889345
10	Forest	560137	4889263	560119	4889259
11	Field/Forest	560159	4889260	560144	4889262
12	Field/Forest	560149	4889239	560160	4889245
13	Field	560216	4889194	560220	4889205
14	Shrub	560194	4889195	560185	4889205
15	Field	560184	4889185	560176	4889193
16	Field/Shrub	560171	4889179	560164	4889189
17	Field/Shrub	560102	4889339	560104	4889326
18	Field/Shrub	560067	4889351	560075	4889359
19	Field	560073	4889354	560074	4889345
20	Field	560047	4889181	560035	4889176

Seawall					
		Start		End	
Net	Habitat Class	Easting	Northing	Easting	Northing
1	Forest	555171	4898724	555172	4898714
2	Forest	555182	4898752	555188	4898759
3	Forest	555170	4898748	555182	4898752
4	Forest	555152	4898731	555162	4898743
5	Forest	555143	4898724	555152	4898731
6	Forest	555139	4898710	555140	4898713
7	Forest	555530	4898766	555541	4898764
8	Forest	555543	4898758	555552	4898756
9	Field/Shrub	555511	4898608	555512	4898595
10	Shrub	555513	4898592	555522	4898589
11	Shrub	555495	4898598	555507	4898591
12	Shrub	555484	4898602	555498	4898606
13	Shrub	555475	4898598	555481	4898596
14	Shrub	555469	4898599	555475	4898598
15	Field	555416	4898522	555420	4898511
16	Field	555425	4898522	555434	4898513
17	Field	555388	4898537	555387	4898524
18	Field/Shrub	555337	4898577	555350	4898574
19	Field/Shrub	555350	4898603	555360	4898595
20	Field/Shrub	555332	4898635	555343	4898630
21	Field	555420	4898537	555422	4898532

MacFarland					
		Start		End	
Net	Habitat Class	Easting	Northing	Easting	Northing
1	Field/Forest	559004	4914024	559007	4914010
2	Forest	558982	4914086	558985	4914098
3	Shrub	558971	4914065	558967	4914078
4	Field	558971	4914065	558967	4914078
5	Field/Forest	558949	4914112	558959	4914123
6	Field/Forest	558967	4914121	558980	4914123
7	Field	558968	4914136	558975	4914147
8	Field	558981	4914161	558986	4914146
9	Forest	558900	4914144	558893	4914130
10	Forest	559009	4914124	559017	4914133
11	Field/Forest	558916	4914132	558922	4914122
12	Field	558900	4914144	558893	4914130
13	Forest	558855	4914179	558853	4914168
14	Field	558852	4914109	558854	4914097
15	Forest	558805	4914086	558815	4914094
16	Field/Forest	558847	4914077	558860	4914080
17	Forest	558815	4914065	558828	4914071
18	Field/Forest	558851	4914011	558864	4914006
19	Field/Shrub	558897	4913944	558893	4913932
20	Field/Forest	558879	4913942	558892	4913939

Appendix C. Banding Totals by Species for the Complete Fall 2010 Season

Species	*MacFarland Hill*	*Seawall*	*Great Duck Island*
Myrtle Warbler	644	106	21
White-throated Sparrow	54	82	48
Swainson's Thrush	50	26	20
Black-capped Chickadee	42	325	5
Slate-colored Junco	41	20	33
Hermit Thrush	38	31	9
Red-eyed Vireo	32	63	95
American Robin	30	35	2
Song Sparrow	23	83	37
Northern Waterthrush	19	6	20
Golden-crowned Kinglet	16	48	47
Blackpoll warbler	15	17	6
Black-throated Blue Warbler	13	3	9
Yellow Palm Warbler	13	10	12
Blue Jay	12	3	0
Black and White Warbler	10	7	23
Ovenbird	10	0	5
Veery	10	3	4
Nashville Warbler	9	6	3
American Goldfinch	8	14	1
Black-throated Green Warbler	7	3	3
Cedar Waxwing	7	3	171
Ruby-crowned Kinglet	7	4	17
Brown Creeper	6	5	28
Purple Finch	6	8	32
Yellow-shafted Flicker	6	0	47
Common Yellowthroat	5	36	16
Savannah Sparrow	5	6	23
Blue-headed Vireo	5	10	14
Magnolia Warbler	4	8	7
Northern Parula	4	15	4
Swamp Sparrow	4	62	14
America Redstart	3	14	23
Indigo Bunting	3	0	0
Least Flycatcher	3	8	6
Sharp-shinned Hawk	3	2	3

Species	***MacFarland Hill***	***Seawall***	***Great Duck Island***
Baltimore Oriole	2	1	10
Eastern Phoebe	2	2	7
Wilson's Warbler	2	2	13
Western Palm Warbler	2	0	1
Yellow-breasted Chat	2	7	3
Yellow-bellied Sapsucker	2	2	20
Bay-breasted Warbler	1	1	0
Canada Warbler	1	1	3
Chestnut-sided Warbler	1	0	3
Eastern Bluebird	1	0	0
Hairy Woodpecker	1	0	0
Lincoln's Sparrow	1	6	4
Orange-crowned Warbler	1	0	0
Red-breasted Nuthatch	1	3	1
Scarlet Tanager	1	1	4
Winter Wren	1	0	0
Wood Thrush	1	1	0
Yellow Warbler	1	15	1
Yellow-billed Cuckoo	0	1	2
White-crowned Sparrow	0	2	3
Rose-breased Grossbeak	0	0	3
Philadelphia Vireo	0	2	3
Painted Bunting	0	0	1
Olive-sided Flycatcher	0	0	1
House Wren	0	0	1
Gray Catbird	0	70	5
Yellow-bellied Flycatcher	0	0	9
Gray-cheeked Thrush	0	0	3
Merlin	0	0	1
Mourning Warbler	0	0	1
Eastern Towhee	0	0	1
Carolina Wren	0	0	3
Nelson's Sharp-tailed Sparrow	0	2	0
Downy Wood pecker	0	2	0
Warbling Vireo	0	2	0
Black-billed Cuckoo	0	1	0
Tennessee Warbler	0	1	0
Willow Flycatcher	0	1	0

Appendix D. Fixed Area Survey Methodology

1. Defining the Survey Areas

Establish survey areas *of a known size* in different habitat types that are suitable for your site. Habitats could include:

- Field/forest edge
- Field/shrub edge
- Shrub interior (along net lanes)
- Forest interior (along net lanes)

The size of each habitat patch can be different, but each area *must* be thoroughly surveyed in 15 minutes even on the busiest days (on the busiest days you may not have enough time to identify every bird to species, but you should be able to cover all the area) and habitat patches should not be so small that during most days zero birds are detected. Start your patch size at approximately 2500m^2 and adjust accordingly within the first week of surveys.

Flag the survey areas with tape and *only count birds inside the borders*.

If there are spots within the survey areas where the borders are unclear, use more flagging tape!

It is critically important that we know what the size of the surveyed area is during every survey day. So, if you do not survey the entire region for some reason, measure how much area you *did* survey during that day (adjust the survey area so you can avoid partial surveys in the future, however).

2. Conducting the Surveys

Each survey should take 15 minutes. These are "fixed effort surveys", which means we are quantifying how much time you are spending in a certain area, but the precise route you take within the area can be determined by bird movement.

During the 15 minutes, thoroughly cover the defined area *only counting birds seen within the defined boundaries*. You should record the following data:

a. Number of birds
b. General bird taxonomic group (sparrow/warbler/blackbird, etc)
c. Bird species
d. Bird sex

The list above is also the order of the data priority. Your first priority is to get the number of birds, then the general taxonomic group, etc. If you cannot complete the first two on a busy day, make your fixed area smaller. You may not be able to get precise species ID or sex when there are concentrations of birds in the area.

Count all birds that are actively using the habitat within the fixed area (perching, flying between perches, etc.). Feel free to note birds that are flying *over* the area if you have the time, but this is not a priority. You should, however, *make sure to note birds that are flying over separate from those that are using the habitat*. There is a field for this in the data spreadsheet, but make sure to distinguish these birds in your field book (e.g. with an 'F' for flyover).

Do not use "pishing" or other attractants to get better looks at birds. The use of these strategies may attract birds to the area and bias our estimates of bird density. If, after the 15 minutes are over, a flock is still in the area, you may pish them closer to ascertain species or sex at that point. But do not pish *during* the 15 minutes.

3. Planning Survey Time & Order

Survey two habitats each day (for 15 min each), either early in the morning (between sunrise and two hours after sunrise) or later in the morning (between 2 hours and 4 hours after sunrise).

Make sure to note the *precise* start and stop time for *each* survey regardless of the period within which you conduct the survey. You should rotate between habitats and times of the day such that every habitat is surveyed during every time block in relatively equal proportion over the season. See the rotation-schedule sheet for a more thorough explanation of this factorial design.

Fixed-area surveys should not be conducted in net lane habitats (shrub or forest interiors) within one hour of net operation. Thus on the mornings that these habitats are being surveyed, nets should be closed (or remain closed) for one hour prior to surveys to prevent net operation from influencing bird habitat use during the survey. Nets can be (re)opened immediately after surveys are completed.

Appendix E. Vegetation Sampling Protocol

Fall Migratory Monitoring Stations
MCINWR, US Fish & Wildlife Service
ANP, National Park Service
University of Maine

General Description
The following protocol was designed to quantify the vegetation of migration monitoring stations within the habitats sampled by A) mist-netting stations and B) daily fixed area censuses (both with an emphasis on vegetative structure and foraging resources).

The protocol consists of vegetative characterization on two time scales (weekly and once per season) at a small spatial scale that can be combined to assess larger spatial scales. The intent of this design is to allow for the assessment of local habitat covariates of net capture rates and fixed-area census results, as well as to allow for the characterization of the overall vegetation (or habitat zones within each site) that is being sampled by different groups at different sites.

General Design
We assume that the local sites are assessing bird habitat use through both mist-netting and daily surveys in areas outside of the established net lanes (Fig. A1). Modifications from this protocol that still allow for comparable data among monitoring stations are simple if only one of these approaches are being followed at any given site. Likewise, if local stations have stratified effort (by habitat type or any other factor of interest), this protocol is easily stratified as well to allow local stations to gather pertinent habitat data along local categories of interest while still providing net-lane, census area, and site level assessments that are directly comparable across multiple stations.

Fig. A1. The general assumed study design of a migratory monitoring station with net lanes (black lines) and fixed-area census area (dotted polygon outlines). The protocol allows for the two sampling methods to be stratified by any categorical treatment of interest (shown here in different colors, e.g. general habitat type, landscape history, land ownership, etc.), but this is not necessary.

We constructed the methods described largely by modifying those described in the *Handbook of Field Methods for Monitoring Landbirds* (Ralph et al. 1993), the US Fish and Wildlife Service's Landbird Monitoring Protocol (Knutson et al. 2008) and the USFWS *Protocol for the Rapid Assessment of Fruit Abundance on New England National Wildlife Refuges* (Smith and McWilliams 2009). Where possible, the methods for gathering data under this protocol have been described to match these previous protocols to allow for wider regional comparisons. However, we have modified these protocols when:

1. The methods from these protocols were inappropriate for censuses of populations in migration (the first two of the established protocols were designed to accompany standard breeding bird surveys),
2. The methods from these protocols were inappropriate for vegetative characterization during a time-period that includes leaf drop,
3. The methods from these protocols included sampling at a larger scale than that sampled by the migration station census or banding protocols
4. The methods from these protocols included the use of categorical indices that necessitated lengthy training of crews to ensure systematic application across technicians, crews, and sites (a feat that is difficult to maintain across multiple PI's, sites, and years).

Survey Placement

All of the surveys described below should occur in a series of belt transects that are 4-m wide and vary from 6 – 12 m in length (precise length can be varied by site, net size, or investigator interest, since all final measures will be transformed to a standard length – e.g. *per meter* – to allow for comparisons among stations). Two transects should be placed parallel to each net lane (one on each side of the net at a distance of 5m from the net) and two of a similar size should be

placed randomly within the fixed-area census plots (Fig. A2). The transects that run along nets should be far enough away that the area disturbed by the cutting of the net lane is not being sampled. The two transects within the fixed area census plot should each begin at a random point and proceed in a random direction, so long as the two transects do not overlap and the entire transect is contained within the survey area.

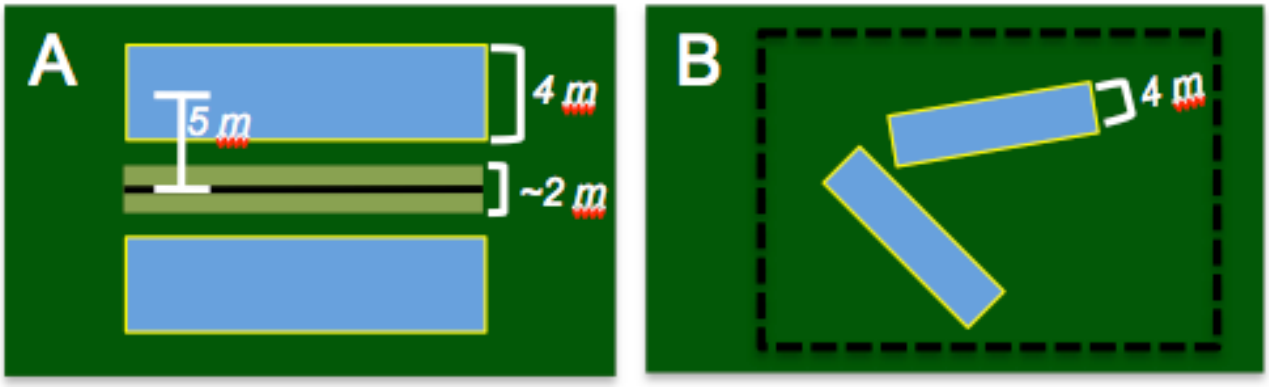


Fig. A2. Size and placement of the two belt transects (blue rectangles) for vegetative sampling A) along each mist-net lane (shown in light green with black line to indicate net) and B) within each fixed area census plots (shown with dotted polygon outline that is not to scale).

Weekly Surveys

The belt transects described above should be sampled at least once per week throughout the monitoring period (the period of bird capture or census) to assess

- The timing and abundance of fruiting,
- The timing and degree of leaf drop
  (a similar protocol could be followed for leaf out during spring monitoring),
- The flux in water availability

These factors are highly dynamic within the monitoring period, likely impact bird habitat use and/or the detection of individuals, and would not be categorized well by more infrequent surveys.

Fruiting Surveys

During each weekly transect visit, researchers should note the species of fruiting plant (a simple list), the state of fruit ripeness, and the rough abundance of fruit (by plant species). To assess "fruit state" for the transect, the rough percentage of fruit that falls into each of the following four categories should be noted:

1. Unripe
2. Ripe
3. Past Ripe (visual blight, wrinkling or drying)
4. Bare stems (on plants that still possess fruit in some state)

To assess fruit abundance, the number of individual fruits should be estimated for each species using the scale developed by Smith & McWilliams (2009)*:

1. <10
2. 11-25
3. 26-100
4. 101-250
5. 251-1000
6. 1001-3000
7. 301-10000
8. >10000

Leaf-drop Surveys

During each weekly visit, researchers should also assess the percentage of leaves in four broad categories:

1. Green Leaves (each leaf is >90% green)
2. Turning/Turned Leaves (individual leaves are <90% green and less than 50% brown)
3. Brown Leaves (individual leaves are >50% brown)
4. Bare Stems (% of leaf drop)

These categories should be assessed for each of three vegetative "layers" for each transect:

- Tree layer (> 5 m)
- Shrub layer (0.5 – 5 m)
- Herbaceous layer (< 0.5 m)

Soil Drainage / Water Availability

Each week researchers should also not whether the surface soil within a transect is generally:

1. Dry
2. Moist but not saturated (no squishing)
3. Saturated (squishing)
4. Standing water present in low spots

Seasonal Surveys

Full transect characterizations will occur once over the season. We recommend the end of the season (especially for canopy height measurements to ensure the best visibility), but noting the date is important regardless.

* It should be noted that the original protocol developed by Smith and McWilliams (2009) for assessing fruiting notes the number of fruits *on each individual woody plant*. Here we have modified this protocol to estimate fruiting abundance category for the entire transect (to minimize survey time) and to include herbaceous fruit (as some fall berries can be very important for migrating songbirds). If individual sites want their numbers to be comparable to other FWS refuge fruit surveys, the numbers gathered under the standard Smith and McWilliams (2009) protocol can easily be summed to obtain the numbers under this protocol for woody plants as long as herbaceous fruiting species are still assessed for the full transect.

Along each belt transect, the researcher should record:

- A species list of woody plants
- The species group (fern, moss, lichen, or herbaceous) for non-woody plants
- The diameter at breast height (dbh) of any tree with a dbh > 7cm
- The dominant ground cover (>50%) component for the area below 0.5 m:
    - Graminoids (grasses/sedges/rushes) **GR**
    - Forbs (leafy flowering plants) **FO**
    - Ferns **FE**
    - Mosses or other non-vascular plants **M**
    - Forest litter (needles or leaves) **FL**
    - Woody debris (logs, sticks, upturned stumps) **WD**
    - Rocks **R**
    - Soil **S**
    - Woody veg (blueberries) **WV**
    - Other (and describe)
- The presence or absence of a "distinct" vegetative layer in each of the Tree (>5m), Shrub (0.5-5m), Herbaceous (<0.5m), or Ground (mosses and lichens 0 <0.1m) zones. The layer should only be counted if it is continuous enough so an appropriately sized squirrel/monkey/wood nymph could move through the layer without touching the ground.
- For each of these four layers, record the species with the greatest cover (casts the most shadow at high noon).

Down the center of each belt transect at 0.5 m high, the researcher should stretch a tape measure or a rope with decimeters marked on it.

- For every third decimeter, the number of stems (not leaves) that touch the rope should be counted (i.e. from 0-10 cm, 30-40 cm, 50-60 cm, etc.)
- Measure the height of the tallest stem above every third meter interval (i.e. 0, 3, 6, 9, and 12m) using an inclinometer
- Repeat these measures with the rope held 1.5 m high (the canopy measure should be the same and can be measured only once)